Profiling Research on PFAS in Wildlife: Protocol of a Systematic Evidence Map and Bibliometric Analysis

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Protocol

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Abstract

Background: Per- and polyfluoroalkyl substances (PFAS) are a large group of manufactured chemicals. Since the beginning of their commercial manufacturing in the 1950s, PFAS haven't only found their way into numerous industrial and commercial applications, but also into the bloodstream of the majority of the human population, the natural environment and its wildlife. Exposure to high levels of PFAS can create health risks for humans and animals which may exacerbate the effects of other anthropogenic impacts faced by wildlife species. To gain a comprehensive overview of the abundance and distribution of PFAS in wildlife species, and to better understand the risk of PFAS exposure on threatened species and PFAS transfer into human food chains, we will collate the available literature into a systematic evidence map and bibliometric analysis.

Methods: We will conduct a comprehensive systematic literature search on Scopus, Web of Science and the 'grey literature'. For screening purposes, we will use decision trees, scanning title, abstract and keywords first. The next step includes full-text screening performed by two reviewers. We will only consider publications in English, peer-reviewed articles, pre-prints and theses. We will limit our search to 31 PFAS types (based on a previous study). A pilot search on Scopus resulted in ~250 potentially relevant publications. We will scan all publications included in the systematic map for predetermined indicators of quality and potential study-level biases. In addition, we will extract bibliometric records from Scopus and perform network analysis. We will present the results using a narrative summary, tables (database), bar plots and colour-coded maps. Results will be available on a dedicated freely accessible website.

Discussion: This study will provide critical insight into the gaps and clusters of the literature with regards to the PFAS concentration in wildlife. Therefore, our study will inform and direct future research efforts to fill the gaps revealed.

Systematic review registration: osf.io osf.io/gnt2y

Background

Rational

Per- and polyfluoroalkyl substances (PFAS, also spelled PFASs) are a group of 5,000 to 10,000 organic chemicals commonly used in numerous industrial and commercial applications worldwide [1]. PFAS are exclusively synthetic, and thus do not naturally occur in the environment [2]. They are water and oil repellent and have a high persistence. These chemical properties have made them favourable additives to many different products and industrial applications. Some of the best-known and widely distributed of those are the fluoropolymer Teflon, the stain-resistant coating Scotchguard and aqueous film-forming foam (AFFF) [2–5]. One of the downsides of PFAS is their extreme persistence, high mobility, and ubiquitous distribution throughout the environment. PFAS accumulate in the environment and bind to human and animal blood proteins [6–9]. Some studies have also presented evidence for a link between PFAS exposure and health effects in humans [10] and wildlife [11, 12].

PFAS include per- and polyfluoroalkyl substances. In perfluoroalkyl acids (PFAA), every hydrogen atom on the carbon chain has been replaced by fluorine, whereas in the polyfluoroalkyl acids this is not the case, as only some hydrogen atoms have been replaced here.

PFAS can be divided into long-chain and short-chain substances. Perfluoroalkyl carboxylic acids (PFCA) – with seven or more fully fluorinated carbon atoms ($C_nF_{2n+1}COOH$; $n \geq 7$; e.g., PFOA) – and perfluoroalkane sulfonic acids (PFSA) – with six or more ($C_nF_{2n+1}SO_3H$; $n \geq 6$; e.g., PFHxS) – are considered long-chain PFAS and tend to accumulate in biota and the environment more than their short-chain counterparts (see Table 1 for a list and abbreviations of common PFAS) [13–15]. In addition, PFSAs accumulate to a larger extent than PFCAs of the same perfluoroalkyl chain length. This is thought to be due to their ability to bind to serum proteins more strongly [16, 17].

Table 1

Types of PFAS included in the systematic map. PFAS are listed in their acidic form.

Name of PFAs group	Abbreviation	Full name	CAS Registry No.
Perfluoroalkyl carboxylic acids (PFCA)	PFBA	Perfluorobutanoic/ perfluorobutyric acid	375-22-4
	PFPeA	Perfluoro-n-pentanoic acid	2706-90-3
	PFHxA	Perfluorohexanoic acid	307-24-4
	PFHpA	Perfluoroheptanoic acid	375-85-9
	PFOA	Perfluorooctanoic acid	335-67-1 Perfluorooctanoic acid 95 % | 335-67-1 Perfluorooctanoic acid 95 % | 335-67-1
	PFNA	Perfluorononanoic acid	375-95-1
	PFDA/ PFDeA/ PFDcA	Perfluorodecanoic acid	335-76-2
	PFUnDA/PFUnA/ PFUA/ PFUdA	Perfluoroundecanoic acid	2058-94-8
	PFDoA/PFDoDA	Perfluorododecanoic acid	307-55-1
	PFTrDA/ PFTriDA/ PFTrA	Perfluorotridecanoic acid	72629-94-8
	PFTA/ PFTeDA	Perfluorotetradecanoic acid	376-06-7
Perfluoroalkane sulfonic acids (PFSA)	PFBS/ PFBuS	Perfluorobutane sulfonic acid	375-73-5
	PFPeS	Perfluoropentane sulfonic acid	2706-91-4
	PFHxS	Perfluorohexane sulfonic acid	355-46-4
	PFHpS	Perfluoroheptane sulfonic acid	375-92-8
	PFOS	Perfluorooctane sulfonic acid	1763-23-1
	PFNS	Perfluorononane sulfonic acid	68259-12-1
	PFDS	**Perfluorodecane sulfonic acid**	**335-77-3**
	PFECHS	Perfluoroethylcyclohexane sulfonic acid	335-24-0

Name of PFAs group	Abbreviation	Full name	CAS Registry No.
Polyfluoroalkyl substances derivates	ADONA	4,8-dioxa-3H-perfluorononanoic acid	958445-44-8
Perfluoroalkyl ether sulfonic acids	6:2Cl-PFESA (F-53B)	6:2 Chlorinated polyfluoroalkyl ether sulfonate	73606-19-6
	8:2 Cl-PFESA	8:2 Chlorinated polyfluorinated ether sulfonate	83329-89-9
	Nafion BP2	Nafion Byproduct 2	749836-20-2
Fluorinated polymers	Hydro-Eve	2,2,3,3-Tetrafluoro-3-((1,1,1,2,3,3-hexafluoro-3-(1,2,2,2-tetrafluoroethoxy)propan-2-yl)oxy) propanoic acid	773804-62-9
Perfluoroether alkane carboxylic acids	PFO4DA	Perfluoro-3,5,7,9-tetraoxadecanoic acid	39492-90-5
	PFO5DoDA	Perfluoro-3,5,7,9,11-pentaoxadodecanoic acid	39492-91-6
	HFPO-DA (GenX)	Hexafluoropropylene Oxide (HFPO) Dimer Acid	13252–13–6
	HFPO-TA	Hexafluoropropylene Oxide (HFPO) Trimer Acid	13252-14-7
Fluorotelomer Sulfonates (FTSs)	6:2 FTS/FTSA	h,1 h,2h,2 h-Perfluorooctane sulfonic acid	27619-97-2
	8:2 FTS/FTSA	2-(Perfluorooctyl)ethane-1-sulfonic acid	39108-34-4

While the US-based company DuPont accidentally developed the first PFAS compound in 1938 (Lyons 1994), the company 3M, also US-based, grew into the biggest PFAS producer worldwide and started the commercial manufacturing process of PFOA, PFOS and many other PFAS in the 1950s [19]. Since then, PFOS and PFOA have become the most produced, distributed and researched members of the PFAS family [20, 21]. One of the main applications of PFAS is in AFFF products which included a wide range of different PFAS as active ingredients including PFOS, PFOA, and PFHxS. Due to the effectiveness of AFFF products in controlling hydrocarbon fires, these products have been broadly deployed for training or disaster management across military sites, civilian airports and firefighting training centres since the 1970s [22]. In the 1980s, China joined the growing number of PFAS-producing countries [23, 24]. Thus, as early as 1968 research suggested that PFAS accumulated in the human bloodstream [25]. Ubel et al. [26], Belisle [27], and Yamamoto et al. [28] eventually confirmed Taves' [25] suspicion. Nevertheless, it took

until the early 2000s before a large number of studies left no doubt that PFAS had not only made it into the human body, but also into wildlife [6], the oceans [29], and drinking water [30]. The unique chemical properties of PFAS prevented an earlier detection in the environment, as measurements required specific and particularly sensitive analytical methods that were beyond the capabilities of most laboratories until recent times [6].

In the early 2000s, it also became evident that PFAS had indeed a compromising effect on human and animal health [31, 32]. In the light of such findings, in 2002, the company 3M voluntarily phased out most of its production of long-chain PFAS substances, including PFHxS, PFOS, PFOA and FOSA [33]. As the demand for PFAS still existed, countries like China, Russia and India increased their production [34], whereupon the OECD [35] hypothesized that these countries' PFAS production might have offset the phase out by 3M. In addition, the worldwide production of other PFAS, like PFUnDA, that were of lesser public concern, increased [36]. 3M and DuPont introduced PFBS and GenX as two new short-chain PFAS to replace PFOA [37] and PFOS [38], in 2003 and in 2009, respectively. In the meantime, national and international initiatives began attempts to restrict production and use of the most common long-chain PFAS. Among the most extensive programmes was the 2010/2015 PFOA Stewardship Program, initiated by the US Environmental Protection Agency in 2006, that aimed to eliminate PFOA emissions and production by the eight leading US manufacturers by 2015 [39]. Furthermore, the UN Stockholm Convention on Persistent Organic Pollutants (POPs) was signed by 152 countries in 2000, and vowed to strictly limit the use of PFOS to certain purposes [33]. However, the list of these exempted purposes included most of the common usages, such as photoimaging, firefighting foams, insect baits, metal plating and surface treatment of leather [33]. Moreover, the speed of the implementation of the Stockholm Convention differed significantly across countries. In 2017, China was the only known producer of PFOS, despite having ratified the Stockholm Convention [23]. While PFHxS is currently under review, PFOA was added to the convention as a harmful environmental pollutant to be eliminated by 2019 [23]. Figure 1 shows a short timeline of important events in PFAS-related history of production, use and legal restrictions, since the discovery of these chemicals.

After all, PFAS substances have truly earned their infamous reputation as 'forever chemicals'. However, questions remain as to whether conventions and restrictions are actually reducing PFAS burdens in the humans, animals and the environment, and if so, when this effect will become apparent. In 2018, the UN Environment Programme declared PFOS, PFOA, PFHxS and PFNA as the most frequently detected PFAS worldwide [40]. In the same year, Land et al. [41] published a large systematic review on PFAS concentrations in humans and showed that exposures to PFOS, PFOA and PFHxS, were in decline in North America and Europe, potentially reflecting the impacts of legislated restrictions towards some types of PFAS. On the other hand, in China people are increasingly exposed to PFAS, like PFOS and PFOA, which was presumably due to the recent local peak in production [42]. However, PFAS contamination trends affect not only humans, but also non-human biota. Wildlife is constantly exposed to contaminants in the natural environment. Thus, PFAS burdens in wildlife are expected to reflect those of their habitat, however there is some uncertainty in these patterns (compared to patterns in humans). Depending on the

geographical region and species, longitudinal studies have provided conflicting reports on trends in PFAS abundance in wildlife and the natural environment over the past 20 years [43–45].

PFAS concentrations in wildlife are also relevant in other ways than just reflecting the contamination of our natural environment. Many wildlife species, particularly fish, are an essential part of the diet of people in many different cultures [46]. The assessment of PFAS concentrations in such species is therefore of relevance to public health. Finally, assessing PFAS burdens in wildlife also serves the purpose of conservation management, especially for those species that have already been impacted by anthropogenic threats, such as loss of habitat and climate change. Exposure to ubiquitous PFAS in the environment could be another potential driver of population decline and extinction [11, 12].

Objectives

We aim to perform a comprehensive overview of the existing state of knowledge on the abundance and distribution of PFAS in wildlife species and to investigate factors that affect distribution of research efforts generating such knowledge. Therefore, we will collate the available literature into a systematic evidence map. The systematic evidence map will not only reveal patterns and relationships in existing data, but also identify knowledge gaps. Our main research questions will explore 'when and where the papers were published', 'what the recent trends in publications numbers were' and 'what (e.g., types of PFAS, tissue), where (habitat, location), and when was tested'. With this work, we will create a body of information to complement the systematic map of Pelch et al. [47], who aimed to synthesise the health effects of PFAS in people. In addition, following the research weaving approach that combines the synthesis of evidence and influence [48], we will investigate the collaboration networks among authors and countries.

Methods

This protocol has been prepared in accordance PRISMA-P [49]. The PRISMA - P checklist is attached as an additional file 1. We registered the project on osf.io (osf.io/gnt2y).

Eligibility criteria

To be eligible for the inclusion in the systematic evidence map, studies need to fulfill the following criteria (also presented as decision trees A, B & C, Figs. 1 & 2): The studies have to be journal articles, pre-prints or theses, written in English. We do not set any limits regarding the publication year. Furthermore, the papers should investigate the concentration of one or several of 34 types of PFAS of emerging importance [10, 47]. The included PFAS' names and synonyms are listed in Table 1. The studies' subjects should be wild or feral animal species in which PFAS concentrations were measured. Research had to be performed on individuals that were not kept in captivity and involve whole animals or their parts or products (e.g., eggs, muscle tissue, blood, feathers, liver). In addition to primary literature, we will also collect secondary literature that focuses on PFAS concentrations in wildlife, for performing backward and forward reference searches and for providing context to the included primary studies.

Information sources

For the systematic evidence map, we will identify the relevant peer-reviewed published literature by searching the inter-disciplinary broad-coverage electronic databases Scopus and Web of Science. We will also include grey literature (theses and reports) in our search, using BASE, OpenGrey, Ebsco and the Australian Policy Observatory, as well as the preprint repositories bioRxiv and OSF. We will also perform backward and forward reference searches from the key secondary publications on the topic. We will periodically (every 6 months) update the systematic map until the manuscript is accepted for publication.

Search strategy, study selection and data collection process

Development and piloting

Our search strategy, selection process and data collection process are based on a pilot test. We performed a pilot search (Table S1) in the Scopus database to develop and evaluate our main search strings (Table S2) and scope the available literature. We randomly selected 100 bibliometric records from our pilot search and screened them according to the eligibility criteria. Two people (ML, CV) performed the pilot screening independently using the online software Rayyan QCRI [50] to facilitate the process. Firstly, we screened the bibliometric records using title, abstract and keywords of the studies, using decision tree A (Fig. 2). We excluded 55 papers that did not fit the initial inclusion criteria. As the second step, we screened full texts of publications that had passed the initial screening step, using decision trees B and C (Fig. 3). A total of 29 out of an initial 100 papers passed the second screening step. When the decision of our two reviewers on the inclusion of publications was not unanimous, we discussed and resolved divergent opinions.

To test the data extraction and coding process for the systematic evidence map, the two reviewers (ML, CV) extracted relevant data from 20 included full-text papers using questionnaires implemented in Google Forms. Again, diverging results were discussed and resolved. After the pilot search and data extraction, we adjusted our search strings, refined the decision trees, and data extraction tables (Tables 2 and 3). Informed by the pilot test, our final search strategy will involve searching eight databases. Table S2 presents final search strings formatted according to the requirements of the individual data sources. We will not use date, language or subject limits in our searches. One reviewer will screen the entire search results and extract the data, because the pilot screens for the systematic evidence map showed high consistency between the reviewers (93 % for stage one, 89 % for stage two of the pilot screening process, and 90 % for data extraction). The second reviewer will cross-check the screening and resolve any conflicts. We will follow the two-step process (firstly, screening of title, abstract and keywords, and secondly, screening of full-text), as in the pilot screening, using decision trees A, B and C (Figs. 2, 3). One reviewer will also perform data extraction and coding, with the second reviewer cross-checking the data. For initial data extractions, we will use pre-piloted online questionnaires implemented in Google Forms.

Data management

We will import all literature search results (bibliometric records) to the reference management software Zotero (version 5.0.88). We will remove duplicate records using Zotero function 'Find Duplicates', based on study title and authors. Following this, we will export and upload bibliometric records to Rayyan QCRI [50]. We will also collect full-text studies in Zotero. We will collate the extracted data in three separate spread sheets (Systematic evidence map: Table 2 – first step; Table 3 – second step; Table S3 – additional data; more details below). We will track the numbers of studies retrieved from our literature searches, numbers screened, excluded and included in our systematic review. We will present our workflow as a diagram based on the PRISMA flowchart [49]. We will make the collected data available to the public via a dedicated website. Analysis code will be available via GitHub.

Data coding strategy

We will perform data extraction from full-text studies using data extraction forms and data extraction spreadsheets (Tables 2 & 3). We will use the data extraction form presented in Table 2 to collate study bibliometric details and general study design and scope details (the content extracted in Google Form will be exported into a flat table in .csv format). The bibliometric data extracted at this stage will comprise document title, year of publication, country of research institution of first author and study funding sources. The study details will include type of PFAS studied, timeframes of sample collection, scientific name of the study species, studied habitat, type of animal tissue used for analysis etc. If the required information is missing in the publication, we will contact the study authors. We will use the data extraction form presented in Table S3 to collect additional information regarding the study species, such as conservation status, economical relevance, average weight of adult individuals. This additional table is required, because this information might not be provided in the actual publication itself, but will be relevant for the interpretation of the systematic map as a whole. Table S3 also includes the sources the information can be obtained from. We will first scan the included publication itself for the required additional information. If the publication does not provide the required information on the species characteristics, we will refer to the IUCN Red List [51], the Animal Diversity Web [52] and the AnAge Database of Animal Ageing and Longevity [53]. Other relevant references for other species-related information categories (e.g., charismatic species as defined in Albert et al. [54]) are stated in Table S3. We will use the R package *rattle* [55] to provide a unique identifier for each study species and to link data stored in different extraction tables.

Table 2
Data extraction form, step 1: bibliometric and study data for the systematic evidence map.

Bibliometric information	**Options of answers**
Study ID?	Study ID code
Title of paper?	Text
Year of publication?	Number
Country of research institution of first author?	Text
Study information	**Options of answers**
Did the authors have a conflict of interest?	Yes, No, Not stated
Does the study include a statement of funding?	Yes, No
Did the study receive funding from a governmental institution?	Yes, No, Unknown (no funding stated)
Did the study receive funding from an NGO?	Yes, No, Unknown (no funding stated)
Did the study receive funding from the industry?	Yes, No, Unknown (no funding stated)
Does the publication provide a link to the raw data?	Yes, No
Does the publication provide a link to the analysis code?	Yes, No
Is the study primary or secondary literature?	Primary, Secondary
Was the chosen sample site located near a known source of PFAS?	Yes (distinct source near-by, e.g., known spill, factory), Possibly (diffuse source like large industrialized area near-by), No
Did the study investigate one or multiple species?	One, Multiple
Were temporal trends investigated?	Yes, No
Did the study include measurements of PFAS only (vs. other pollutants)?	Yes, No
Year of sample collection started?	Year
Year of sample collection finished?	Year
Habitat of study species?	Aquatic: marine, estuarine, freshwater; Terrestrial: terrestrial inland, terrestrial coastal

Bibliometric information	Options of answers
Sex of study specimen?	Male, Female, Mixed, Unknown
Developmental stage of study species?	Eggs/ early development (e.g., embryo), Juvenile, Adult, Mixed, Unknown
Did the study investigate functional aspects (e.g., effects of pollutant burden on reproduction)?	Yes, No
Biogeographical region of study species?	Tropical, Temperate, Polar
Type of PFAS investigated?	(34 types, refer to Table 1 for details)
Types of tissue of study species?	Liver, Fatty tissue, Feathers, Eggs, Muscle, Bile, Kidney, Blood, Whole body homogenate, Other
Scientific names of all study species?	Text
General comments/notes?	Text

Study quality assessment

We will check all publications included in the systematic map for the statement of the following information: conflict of interest, funding sources and availability of raw data and analysis code, if relevant. This information could be indicative of study quality and potential study-level biases [56, 57], is easy to extract and comparable across different study types and designs. The sections for related data extraction are included in Table 2. These extracted variables representing study-level risk of bias will be included in the systematic map results.

Data mapping method

To present the extracted data, we will use a combination of tables, plots (e.g., for research questions like 'year of publication', 'year of sample collection, 'conservation status (IUCN) of wildlife species'), and colour-coded maps (e.g., for 'geographical origin of first author', 'biogeographical regions of tested wildlife species'; as used in Mangano et al. [58]. We will make the systematic map publicly available on a dedicated freely accessible website.

Table 3
Data extraction form, step 2: additional information for the systematic evidence map.

General information on study species	Options of answers
Lay name of study species?	Text
Taxonomy of study species (class)?	Text (e.g., Mammalia, Aves, Actinopterygii)
Conservation status of study species (according to IUCN Red List of Threatened Species, 2020)?	Not evaluated, Data deficient, Least concern, Near threatened, Vulnerable, Endangered, Critically endangered, Extinct in the wild, Extinct
Dietary class of study species?	Omnivore, Carnivore, Piscivore, Herbivore
Weight (average of male and female) of study species in g?	Number
Does study species belong to one of the 20 highly charismatic species (according to Albert et al. [54]?	Yes, No
Economically relevant wildlife species (e.g., human consumption)?	Yes, No
General comments/notes?	Text

Data synthesis criteria & Summary measures

We will provide a narrative summary of the systematic evidence map featuring PFAS findings, especially in relation to major events in the history of PFAS (introduction of new types, bans and regulations etc.) (Fig. 1). We will discuss the main findings of the systematic map by pointing out trends, gaps and gluts. For instance, we will elaborate on trends regarding the countries of affiliation of the publications' first authors, providing insight into which countries demonstrate most research activity investigating the issue of PFAS exposure in wildlife. Furthermore, we will discuss which geographical regions the studies mostly focus on and where studies are potentially missing (e.g., here we expect large focus on polar regions and negligence of the tropics). Moreover, we will assess which types of PFAS are most frequently studied and if the general focus lies more on the exposure to phased-out substances, or whether relevant studies exist on the new generation of PFAS, such as HFPO-DA (GenX) and HFPO-TA (for details on nomenclature please refer to Table 1). We will also investigate the collaboration networks across authors and countries using information automatically extracted from Scopus bibliometrics records of the included studies for which full Scopus records exist. We will process these bibliometric records and perform network analyses using *bibliometrix* R package [60].

Discussion

The risk of exposure to high levels of per- and polyfluoroalkyl substances of humans, domestic animals, wildlife and the environment is a major concern worldwide [30, 31]. The use of PFAS and subsequent pollution has been ongoing since the mid-20th century [19]. However, the revelation that action should be

taken only recently became apparent to legislative bodies and the public eye [33, 39]. Since then, a large number of research studies has been conducted to trace the extent of PFAS exposure and its consequences [30, 31]. Wildlife species worldwide are facing a multitude of anthropogenic threats which has led to a wave of extinction and population decline [61, 62]. PFAS exposure adds an additional risk factor to the current situation that should therefore be closely monitored and controlled to keep its consequences at bay [11, 12]. In addition, PFAS in wildlife poses a threat to public health as it enables PFAS to enter the human food chain [63, 64].

The aim of our systematic map and bibliometric analysis is to give a critical overview of those studies performed on the PFAS concentrations in wildlife. Therefore, this study will provide guidance and orientation for further research efforts that aim to close existing knowledge gaps in this important field.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

All materials are available within this protocol. During the review, all materials will be made available in a publicly accessible repository at the Open Science Framework.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

CRediT authorship contribution statement:

CV: Conceptualization, Formal analysis, Methodology, Writing - original draft, Creating of website; MT: Conceptualization, Methodology, Writing - review & editing; JB: Methodology, Writing - review & editing; MG: Writing - review & editing, Creating of website; DH: Writing - review & editing; GN: Writing - review & editing; ML: Conceptualization, Formal analysis, Methodology, Writing - review & editing, Supervision, Creating of website; SN: Conceptualization, Formal analysis, Methodology, Writing - review & editing, Supervision, Funding. CV, ML & SN will be the guarantors of the review.

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Figures

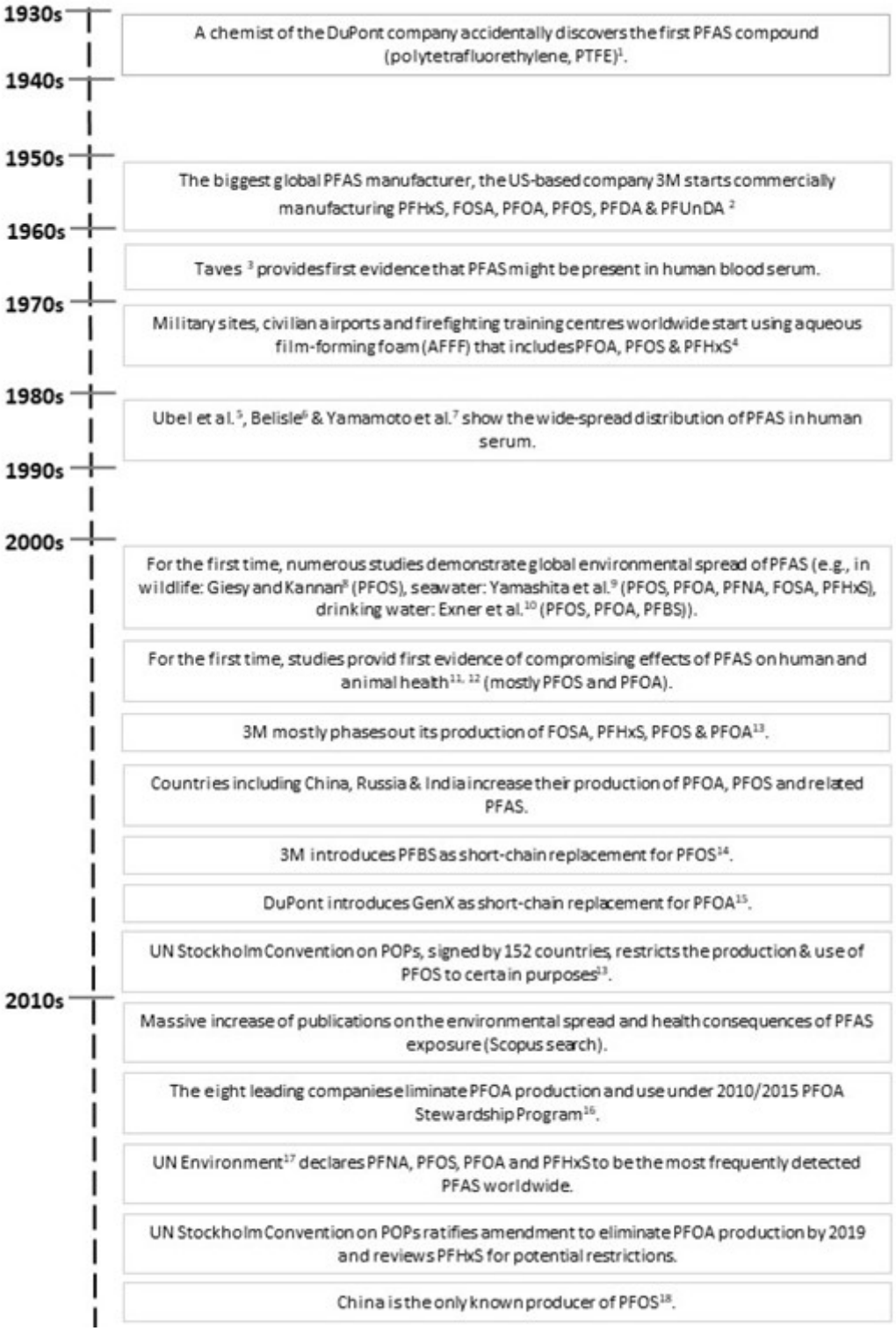

Figure 1

Short historic timeline of selected PFAS-related events including introduction, usage and legal restrictions. Legend: References: 1 – Lyons (1994), 2 – 3M Company (2020), 3 – Taves (1968), 4 – Australian Department of Defence (2020), 5 – Ubel et al. (1980), 6 – Belisle (1981), 7 – Yamamoto et al. (1989), 8 – Giesy and Kannan (2001), 9 – Yamashita et al. (2005), 10 – Exner et al. (2006), 11 – OECD (2002), 12 – Hekster et al. (2003), 13 – Martin et al. (2010), 14 – Olsen et al. (2007), 15 – Ahearn (2019), 16 – EPA (2020), 17 – UN Environment (2018), 18 – Worldbank (2017a)

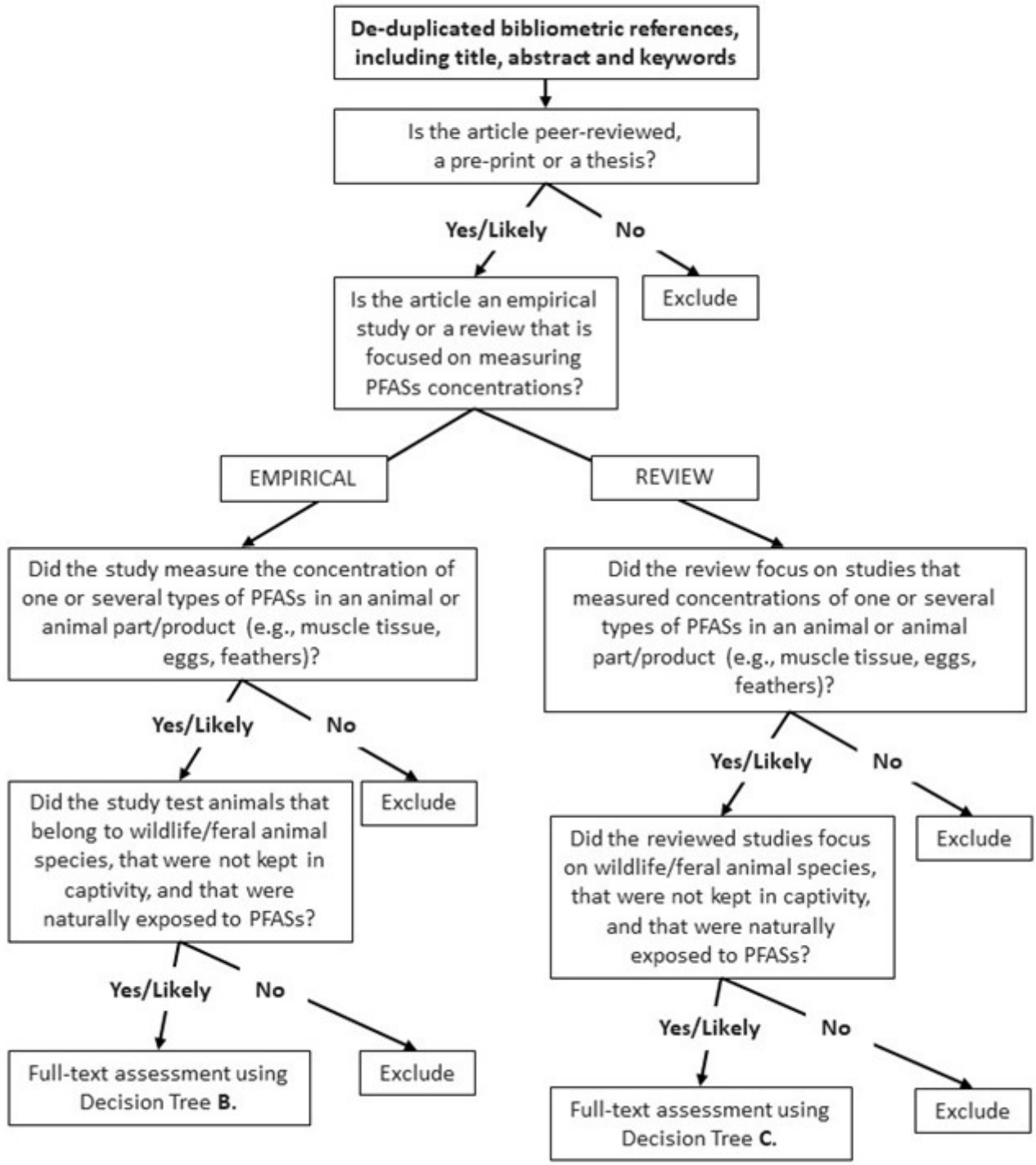

Figure 2

Decision Tree A for initial screening of bibliometric records. Legend: Inclusion criteria for screening title, abstract and keywords of the papers.

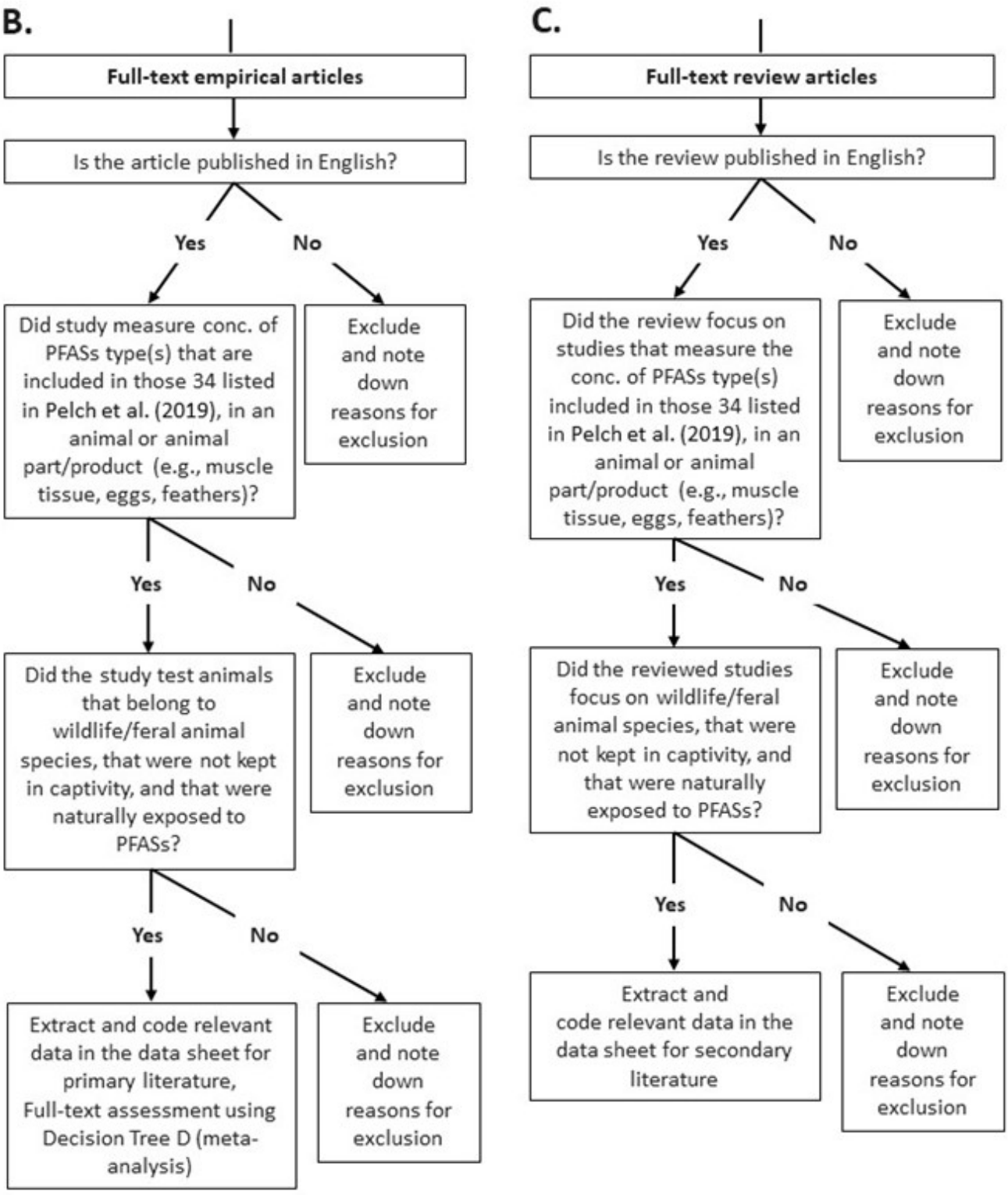

Figure 3

Decision Trees B & C for screening of full-text studies. Legend: Inclusion criteria for screening full-text of studies that passed Decision tree A (Figure 2).

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